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SOIL ORGANIC CARBON DYNAMICS UNDER TEAK PLANTATION IN SOUTHWEST NIGERIA: A GEOGRAPHICAL PERSPECTIVE

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ABSTRACT

The high rate of demand for this exotic timber product all over the world might have led to the over exploitation which has equally led to the current decline in the world natural forest cover. This study examined the differences in the soil physical-chemical properties of Teak plantations under basement and sedimentary rocks in south western Nigeria.

72 soil samples were collected; 36 from each of the two plantations underlying by Sedimentary and Basement complex of Ilaro and Olokemeji respectively. 12 Soil samples each from 3 quadrants each of 30m^2 were selected from each age i.e. 1970, 1972 and 1975 within a site respectively across the two sites. Bulked soil samples were collected each from horizon A and B of topsoil and subsoil with depth of 0-15cm and 15-30cm respectively. Also, 18 soil samples 9 from each site were collected from 3 profiles section from their A, B and C-Horizons. All these samples were analyzed for their organic carbon concentration representing the chemical parameters. The statistical test reveals that there is statistical significant difference between the mean concentrations of Organic Carbon (OC) and the mean concentrations of Phosphorous (P), Potassium (K), Manganese (Mn), Iron (Fe), cupper (Cu) and Zinc (Zn) with P =0.000<0.005 for all the parameters identified..

Keywords: Organic-carbon, Parent materials, Chemical properties ,Plantation, Soil Nutrients.

INTRODUCTION

Teak tree species is in high demand by the timber trade whereas it is difficult to grow in plantations, (Raymond, 1996). The high rate of demand for this exotic timber product all over the world might have led to the over exploitation which has equally led to the current decline in the world natural forest cover. However, the productivity of Teak in most of the countries where they are grown in commercial quantities is generally below their potential.

According to Ombina (2008), the limiting factors explaining the current lower supplies of teak from tropical countries are multiple among which are the species suitability related to the edaphic factors and the land availability for plantations. While the edaphic factors are dictated by nature and have often been improved through different land management practices, the availability of' land imposed by human settling is often the most limiting factor faced by forestry agencies. Therefore, there is need to carry out research on the ecological factors responsible for the change in the [productivity level of teak, especially in the area of the soil in order to sustain the world demand for the exotic timber consumption in the tropical environment.

Most soils are of mineral origin, but their topsoil contains organic matter that, in spite of its low content, is of great importance to many aspects of soil fertility and plant growth. Soil organic matter (SOM) can range from less than 1 percent in many tropical arid and semi-arid soils of the plains to 5 percent or more in temperate regions or under forest vegetation. The average composition of SOM is 47 percent C, 44 percent O, 7 percent H, 2 percent N and very small amounts of other elements. More than half of SOM consists of carbohydrates, 10–40 percent is the resistant material lignin and the rest consists of compounds of N. The whole complex of organic matter along with soil organisms and soil flora is of vital importance to soil fertility. SOM contains the well-decomposed fine humus fraction, small plant roots, and members of the plant (flora) and animal (fauna) kingdoms. SOM plays a role far greater than its share of the soil volume. It is a virtual storehouse of nutrients, plays a direct role in cation exchange and water retention, releases nutrients into the soil solution and produces acids that affect the fixation and release of other nutrients. SOM or "humus" reaches equilibrium during soil formation. Wet and/or cold soil conditions tend to increase the humus content, whereas high temperatures of tropical climates and cropping procedures promote its decomposition. The C:N ratio provides a general index of the quality of SOM, being in the range of 10–15:1 for fertile soils. When organic manures or green manures are added, these become a part of the organic pool of the soil.

However, the knowledge of nutrient quantity in the nutrient stock of the soil, above- and below ground biomass is of fundamental importance to the understanding of a forest ecosystem. A deeper insight into nutrient dynamics is also a precondition for guaranteeing ecological sustainability in these forest plantations (George et al. 1990.In tropical forests, most of the nutrients can be found in the active tree tissues, such as leaves (Whittaker et al. 1979).

The outcome of this study will form the basis for the formulation of better silviculture management strategy for the cultivation of Teak and to establish the best geological formations suitable for the growth of Teak and which will recycle and restore soil nutrients on time. Also, knowledge of the productivity (especially the stem wood biomass) of the species under different geological formations will also be essential to justify differences recorded in timber production under different geological formations which is currently lacking for Tectona Grandis in the study area. In addition, a monitoring system for detecting changes in critical site parameters (especially biophysical and chemical characteristics) under different geological formations is expected to be designed for silviculture monitoring purposes which is one of the major contribution this research intend to add to the study of bio-geomorphology.

The aim of this study examined the relationship between Soil Organic Carbon and other Nutrients in Teak plantations under basement and sedimentary rocks in south western Nigeria. In order to actualize the above aim, the research hypothesis is that there are no significant differences in the Organic Carbon Concentration and other chemical properties of soil of Teak plantations under the basement and sedimentary rocks in the study sites.

STUDY LOCATION AND METHODOLOGY

Two forest reserves located in south-western Nigeria are purposively selected for this study. The reserves fall within the hot humid tropics which support the tropical rainforest ecosystem (Richards, 1952). The two selected reserves are predominantly single-specie plantations of Tectona Grandis located in Olokemeji and Ilaro with large areas of land committed to forest reserves in Ogun state. The two reserves are known to have been sources of enormous economic benefits to Ogun state over the years (e.g Adeyoju 1971; Okali and Onyeachusim, 1991) because of their rich wood resources.

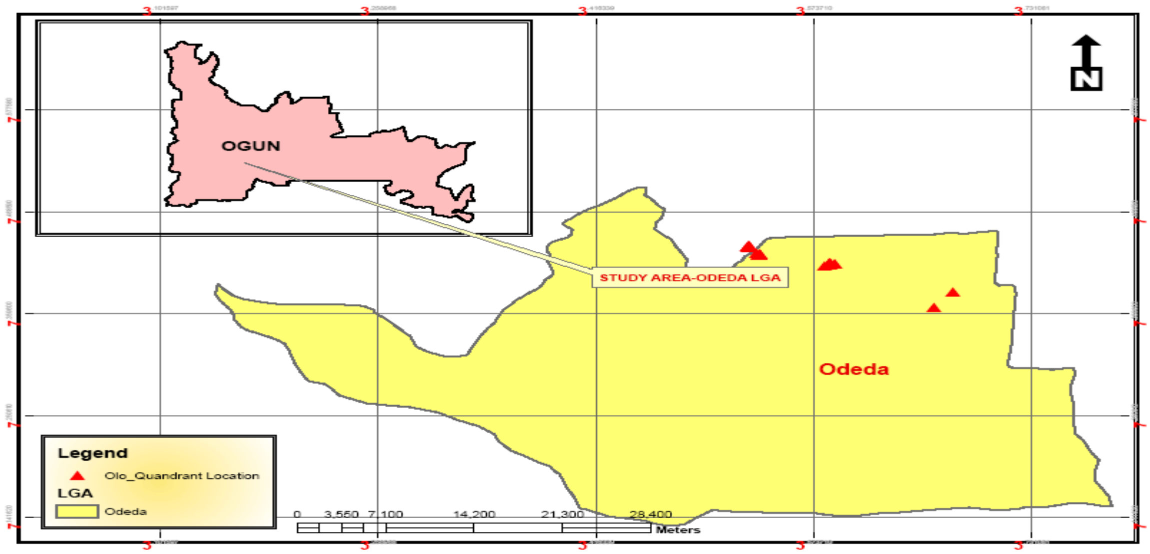

Figure 1: Location Map of Olokemeji teak plantation

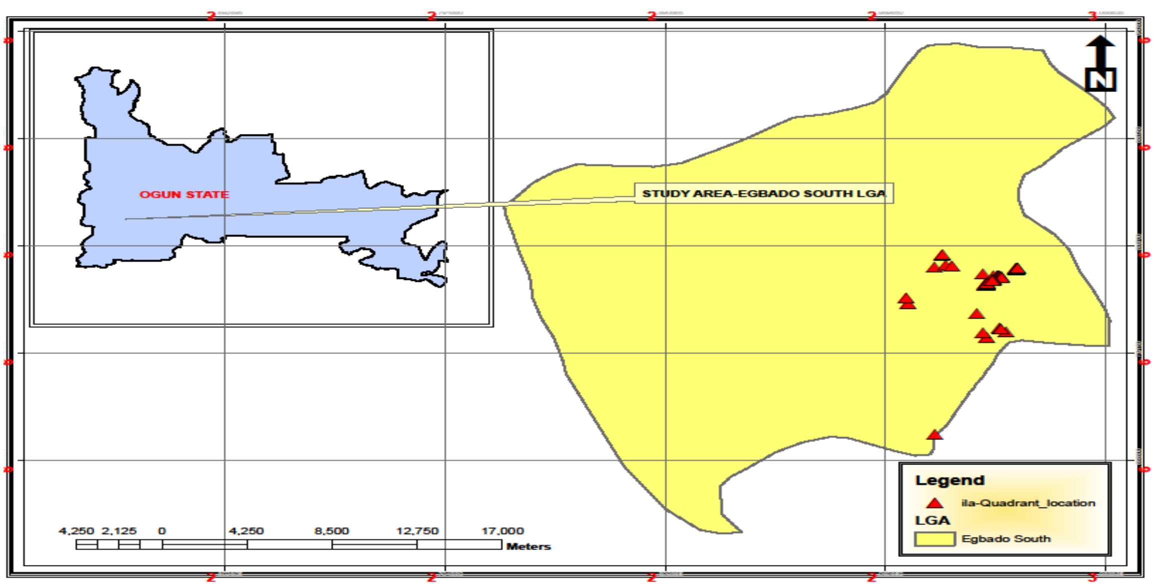

Figure 2: Location Map of Ilaro Teak Reserve

Location and Extent of Olokemeji and Ilaro Plantations

The Olokemeji teak plantation is located in the heart of Olokemeji forest reserve located between latitudes 7° 05' and 7° 40'N and longitudes 3°15' and 3°46'E and occupies a total land area of 58.88 km2 (approximately 5,000 hectares) (Aminu-Kano and Marguba, 1901) .The reserve, which was established in 1899 is the second forest reserve in Nigeria. The site lies approximately 32km west of Ibadan, and 35km north-east of Abeokuta. It falls within the middle course of Ogun River, which drains the western half of the Basement Complex area of South Western Nigeria. On the other hand, geographically, Ilaro is bounded on the north by the Oyo Province, on the South by Lagos, on the east by the Egba Division and on the west by Dahomey (Republic of Benin). The boundary on the South is defined in the "Colony of Nigeria boundaries order in council 1913" (see page 311 of Vol IV laws of Nigeria). Ilaro forest reserve is defined roughly by latitude 06 38' 51.36 N and 06 57' 24.40 N and Longitude 02 49 06.12'E and 03 10 43.60 E. This reserve covers an area of about 34.2 km by 39.9 km.

Plantation Sampling Techniques

Sampling design for this study was based on two premises, first, the need to spread sample sites objectively over the study area and second, the needs to ensure that plant and site characteristics are adequately depicted.

Therefore, in order to obtain detailed soil and plant representation, one Teak reserves each established on Basement Complex and Sedimentary formation parent rocks were purposefully selected and divided into plantation quadrants based on the information extracted from the forest resources study of Nigeria published by FORMECU in 1999.The two teak reserves are Olokemeji and Ilaro in Ogun State, Southwest Nigeria. The two selected teak reserves are distinctively established under basement complex (Olokemeji) and sedimentary (Ilaro) formations respectively (Kogbe, 1976 and Hushley, 1976). The choice of Teak as the study species is because of its high quality as hardwood which led to its high demand and also because almost 90% of the timber species in the two plantation are Teak species.

According to FORMECU (1999), Olokemeji reserve has 15 Teak plantations of 50 hectares of 750 hectares while Ilaro forest has 11 Teak plantations of 550 hectares of fifty (50) hectares sizes. The twenty-six (26) teak plantations were established between 1970, 1972 and 1975 across the two sites which make them 41, 39 and 36 years old respectively. Therefore, due to the uniformity in the area sizes and the ages of the plantations, random and systematic sampling techniques were adopted to select the quadrant plots where various soil and plant samples were collected.

Soil Sampling Techniques

Out of the 26 plantations of 750 and 550 hectares for Olokemeji and Ilaro respectively, six plantations (three each under the basement complex (Olokemeji reserve) and sedimentary (Ilaro reserve) were sub-divided into quadrant plots. This is possible because of the uniformity in plantations sizes and ages based on the records of the Nigeria Forest Inventory carried out BEAK Consults/ FORMECU published in 1999 (FORMECU,1999) . Therefore, in each of the six sampled plantations, 1000 metre long transect was laid from the edge of each plantations as identified by the forest official. Along each of the major transect, 10 sample plots with the size of $900m^2$ (30mx30m) were laid consistently at a right angle to the main transect with the aid of GPS and pegs, making a total of sixty (60) plots for the two sites from where eighteen (18) plots (quadrants) for each site and thirty six (36) for the two sites were randomly selected for enumeration. Data were collected in the 36 sample plots from the six transects representing 0.2769 %.

In each plot (quadrant), five (5) soil samples each were collected from the A-Horizon of 0-15 cm and B-Horizon of 15-30cm representing the top and sub-soils respectively, making a total of ten (10) samples per quadrant plot. The restriction of soil samples to 0–15cm and 15–30cm depth was adopted because the layer provides the bulk of plant nutrients (Russell, 1978). With this, a total of sixty (60) soil samples were collected for the two Horizons per plantation while in all, a total of three hundred and sixty (360) samples were collected from the six plantations for the whole study covering the two parent material.

The soil samples collected were later bulked to reduce the sample size. According to Cameron et al (1971), four aliquots from each grid cell situated from the sides of the cell plus one at the grid centre are sufficient for grid cell of 30m x 30m size.

Following Cameroun et al (1971) sampling procedure, the soil samples collected diagonally from five points in each plot at each horizon were later bulked to make one sample per horizon per plot and two samples for the two horizons per plot with a total of six soil samples per horizon per quadrants plot and twelve (12) soil samples for the two horizons per plantation. Therefore, the total soil samples for the three plantations per geological site after bulking were reduced to eighteen (18) per horizon and thirty-six (36) for the two horizons to make a total of seventy-two (72) samples for the entire study for the two horizons.

Table 1a: Summary of Laboratory Analytical Methods Employed

S/N	PARAMETER	METHOD
1.	Organic carbon	Walkey and Black
2.	Total Nitrogen	Kjedhal/Colorimetry
3.	Salinity as chloride	Orion 105plus meter
4.	Available phosphorus	Bray P-1
5.	Metals	Atomic absorption spectrophotometry [using Perkin Elmer 2380 AAS]
6.	Anions	Spectrophotometry using Palintest 5000 Photometer

Table 1b: Definition of Parameters for Soil and Plant Variables

S/N	PARAMETERS	ELEMENTS
1.	Soil Chemical Nutrient (Macro and Micro)	Nitrogen (N) mg/kg,Organic Carbon (OC),mg/kg,Phosphorous (P) mg/kg, Potassium (K, C mol/kg), Manganese (Mn) (mg/g),Iron (Fe) (mg/g),Copper (Cu) (mg/g), Zinc (Zn) (mg/g)

STATISTICAL ANALYSIS

Data Analysis was carried out using the following tools. The data were subjected to different analysis.

- Descriptive statistics: This include statistic such as the mean (Arithmetic mean) and the Standard Deviation as well as standard error of mean of each of the indices. The analysis of means was also considered to look at each of the statistics by different interaction (Site by year or Site by plot)
- Generalized Linear Model: This was executed using the GLM of SAS version 9. Under this GLM, different sources of variation including both main and interaction effect were investigated.

Also, analysis of means for the main factors-Geographic-sites, plantation age and plots as well as interaction effects of geographic location and plantation age and location and plots . Also, mean separation of the different sources of variation was done using Duncan Multiple range test of the SAS version 9 and Factor analysis was carried out using principal component analysis of the MINITAB (version17) .Specifically, one-way analysis of variance (ANOVA) was conducted for detecting statistically significant differences in soil physicochemical properties, biomass production and distribution, tree nutrient concentrations across geological formations at 0.05 and 0.001 significance levels.

RESULTS AND DISCUSSION

Soil Organic Carbon/Organic Matter

In this study, the higher correlation between organic carbon (OC) and Nitrogen, Potassium, Manganese and Zn in Olokemeji soil signifies the higher reactivity of the clay minerals which is the dominant minerals unlike Ilaro soil which is dominantly sands. This is shown in figures 3a-3o below.

Nutrients and Ions plot Against Organic Carbon of Ilaro Soil

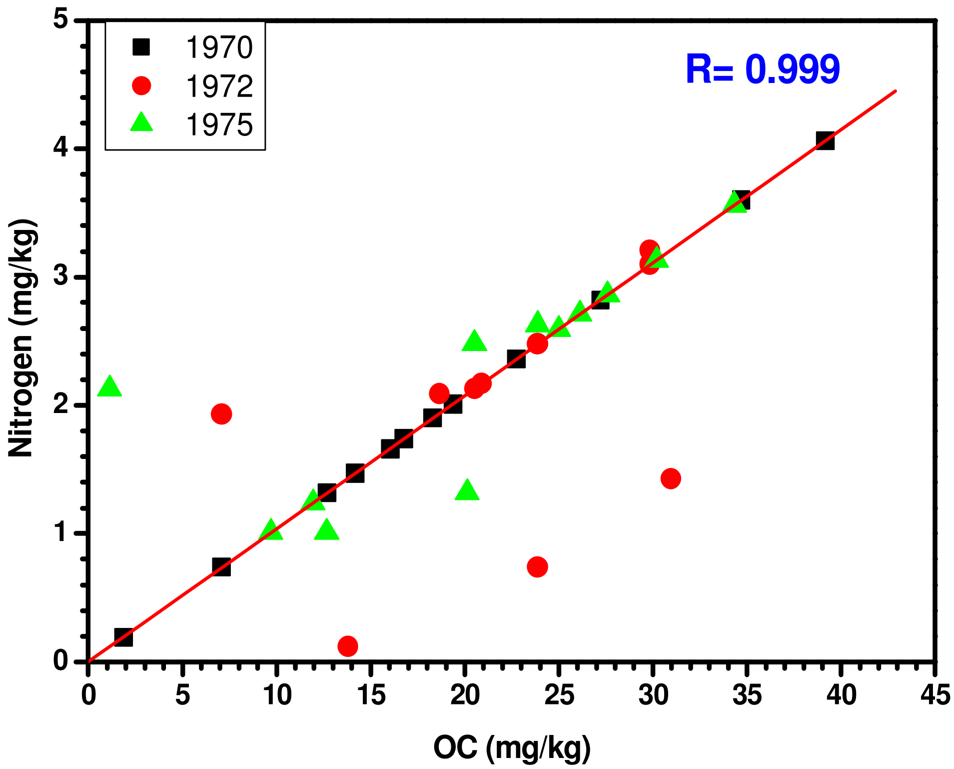

Figure 3a: Scatter Plot of Nitrogen against OC in Ilaro Soil

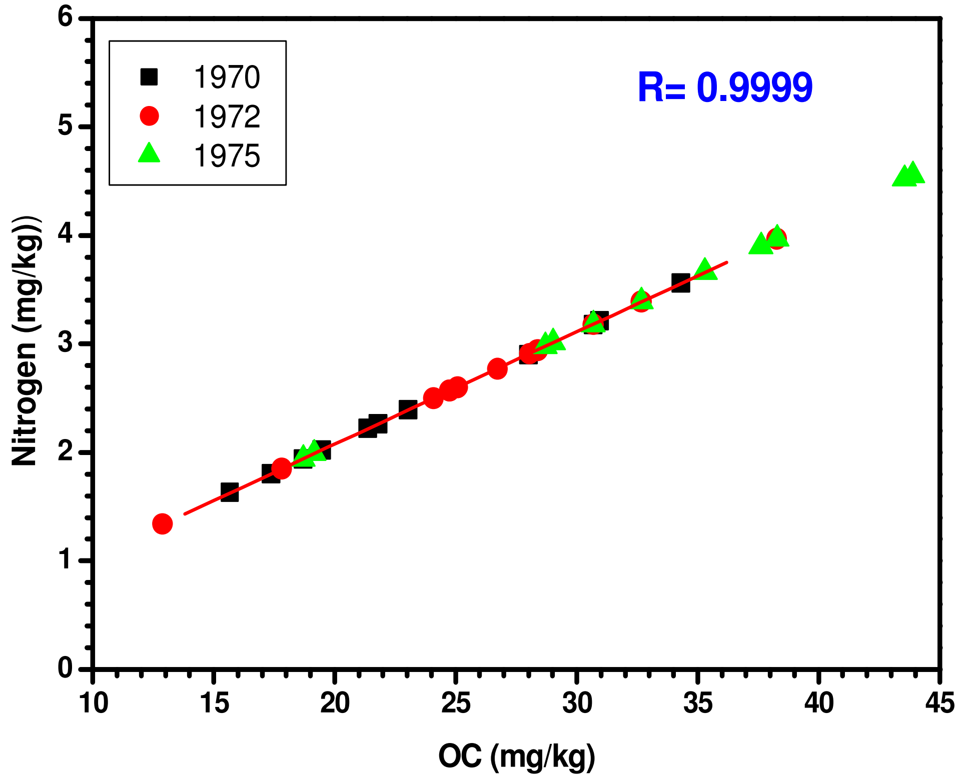

Figure 3b: Scatter Plot of Nitrogen against OC in Olokemeji Soil

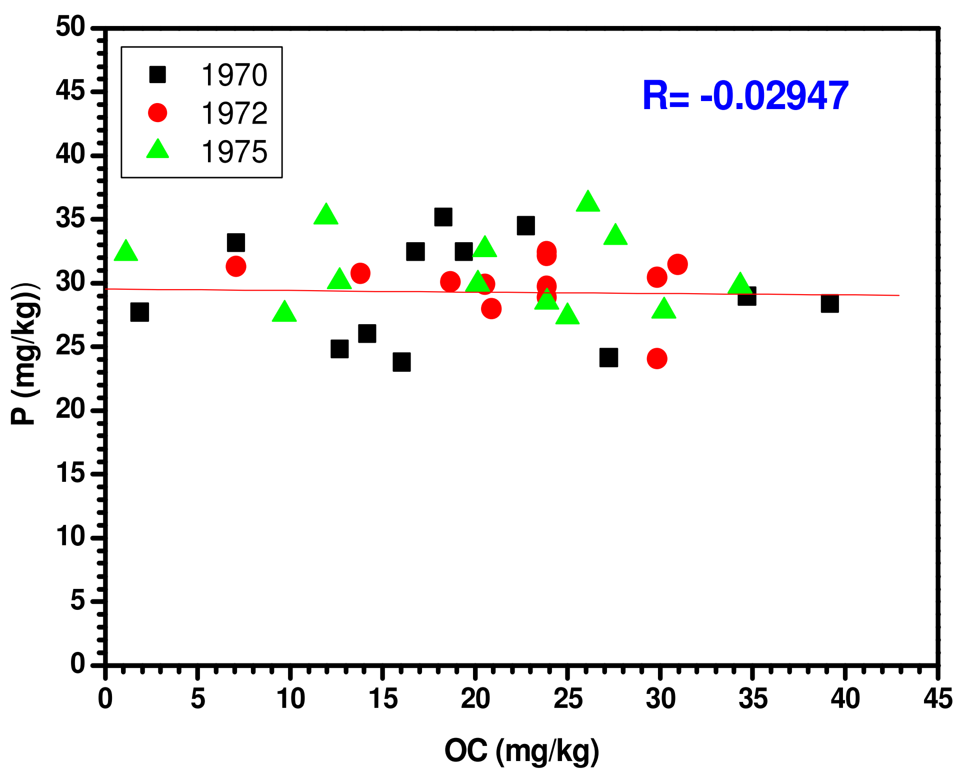

Figure 3c: Scatter Plot of available P against OC in Ilaro Soil

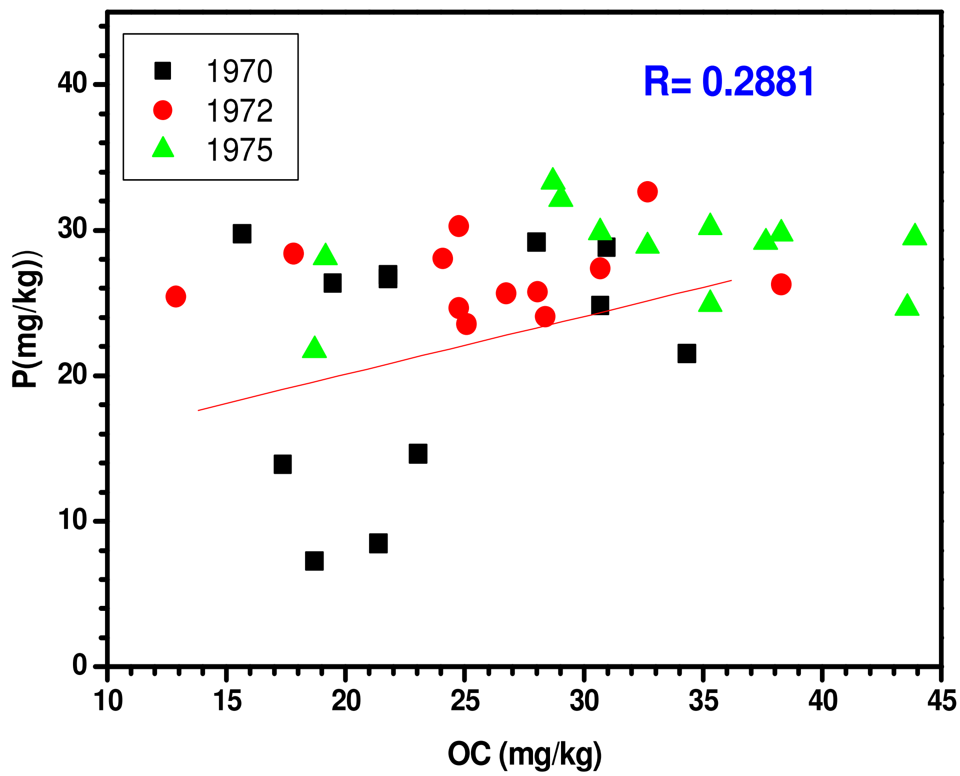

Figure 3d: Scatter Plot of available P against OC in Olokemeji Soil

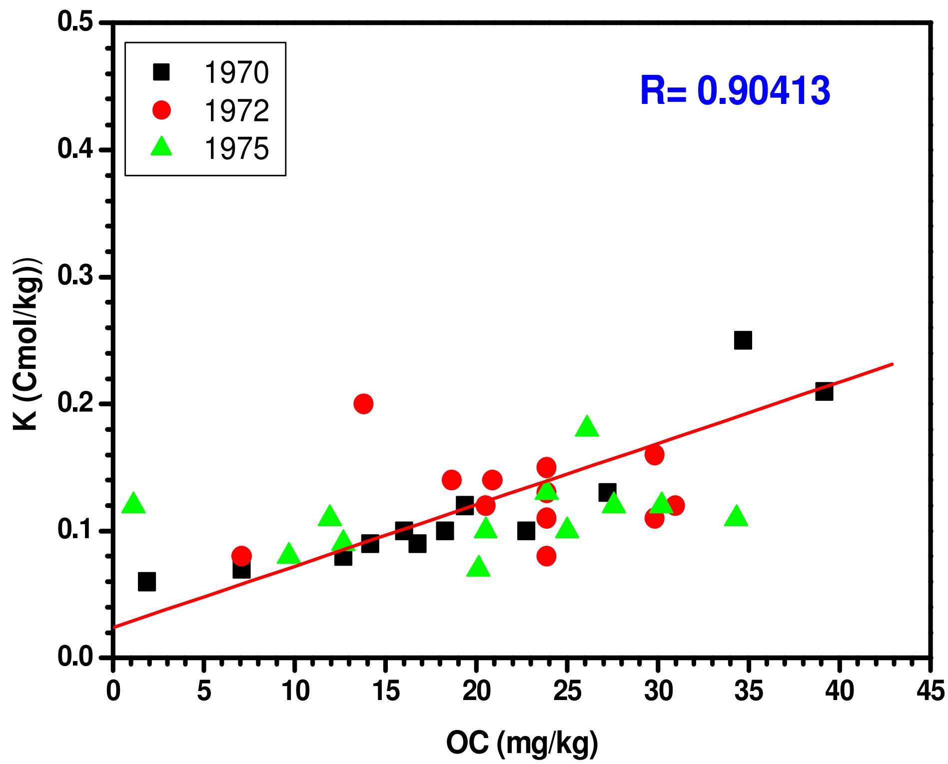

Figure 3e: Scatter Plot of available K against OC in Ilaro Soil

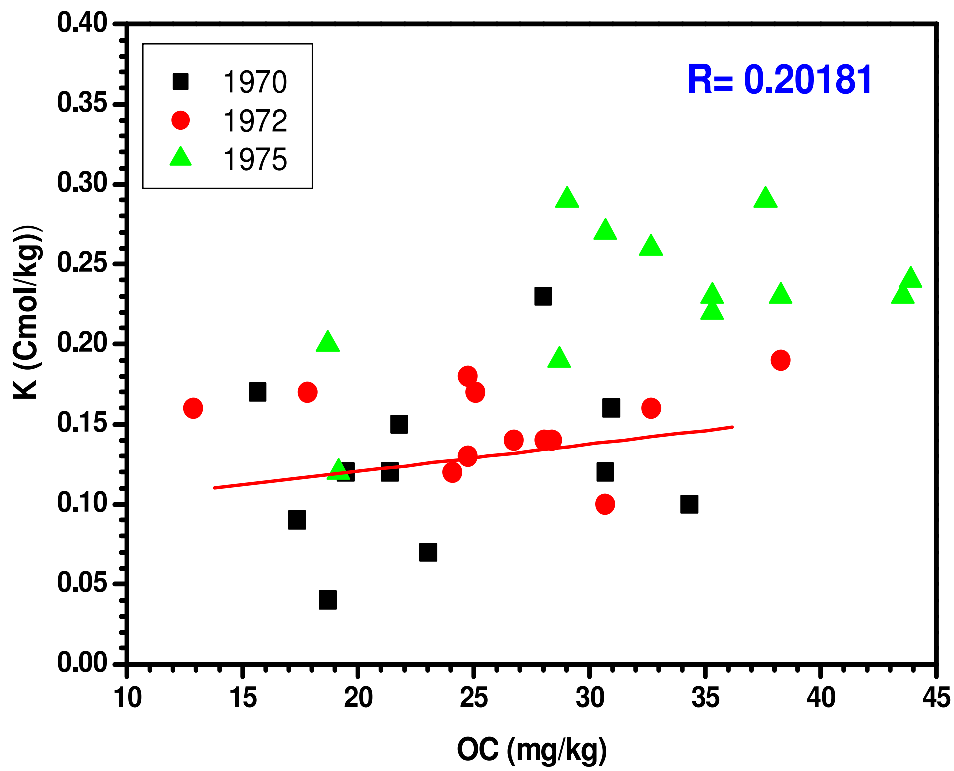

Figure 3f: Scatter Plot of available K against OC in Olokemeji Soil

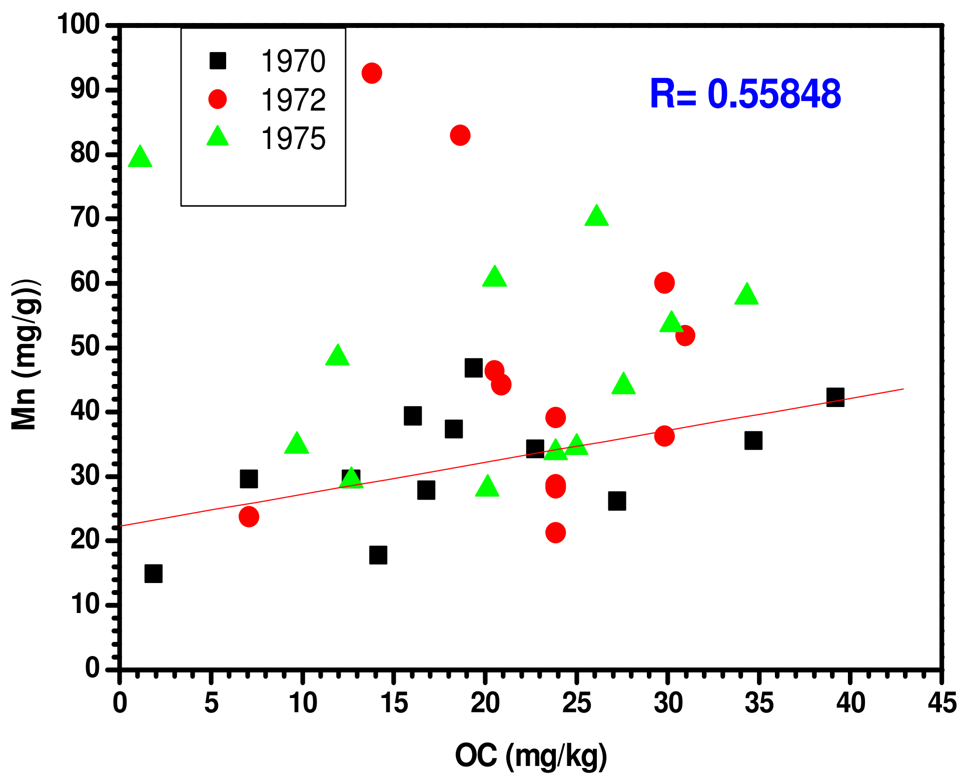

Figure 3g: Scatter Plot of Mn^{2+} against OC in Ilaro Soil

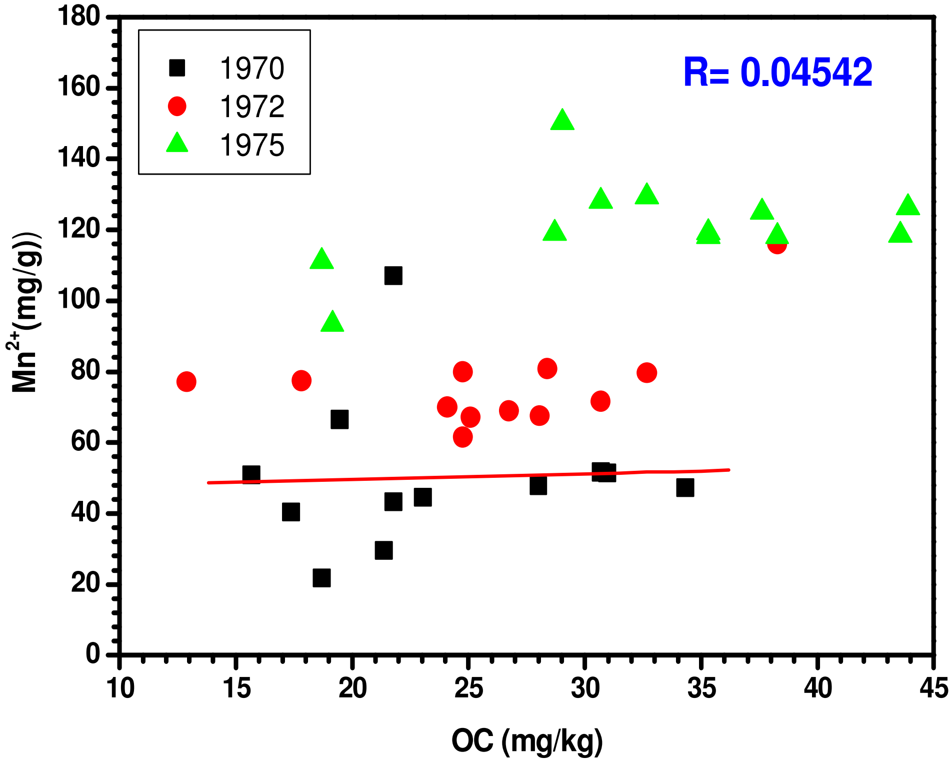

Figure 3h: Scatter Plot of Mn^{2+} against OC in Olokemeji Soil

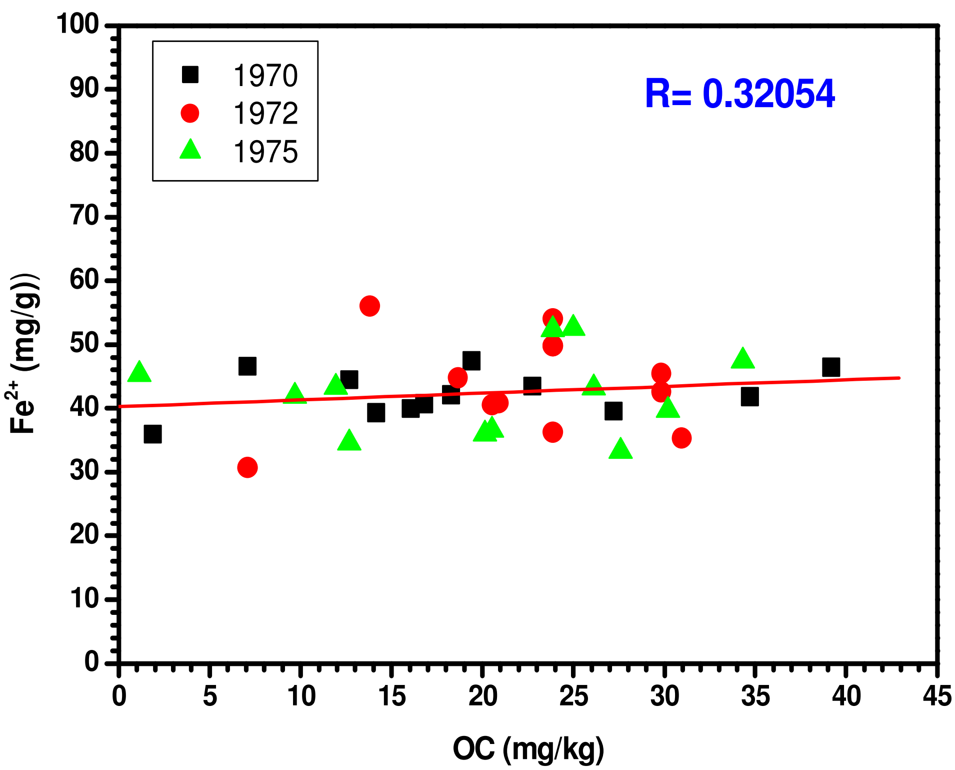

Figure 3i: Scatter Plot of Fe^{2+} against OC in Ilaro Soil

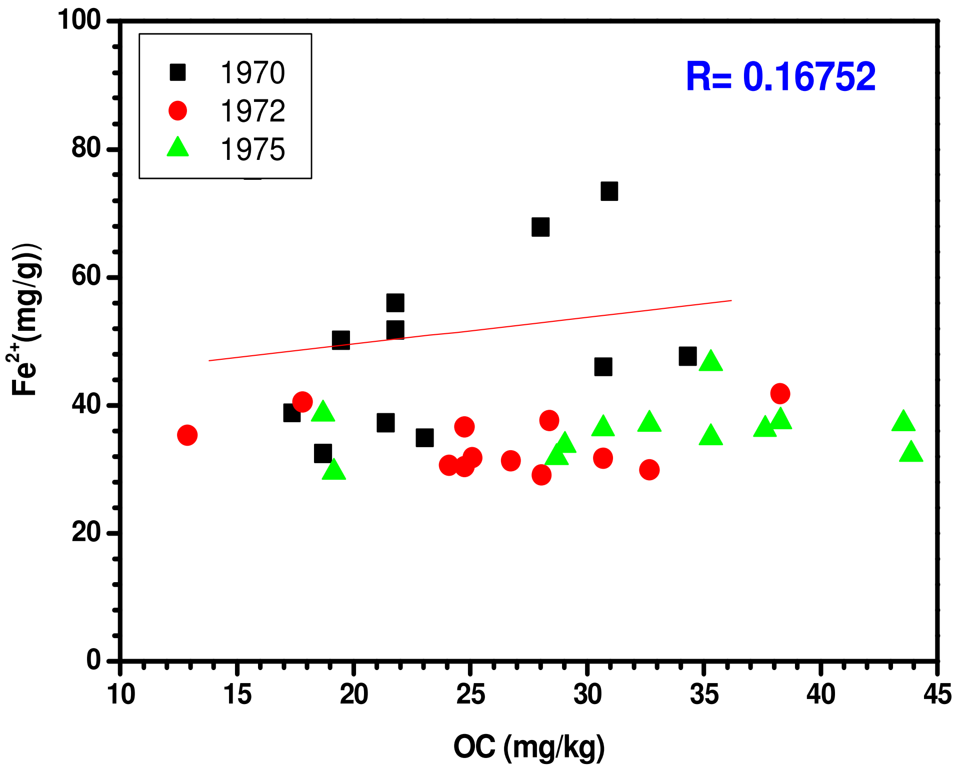

Figure 3j: Scatter Plot of Fe^{2+} against OC in Olokemeji Soil

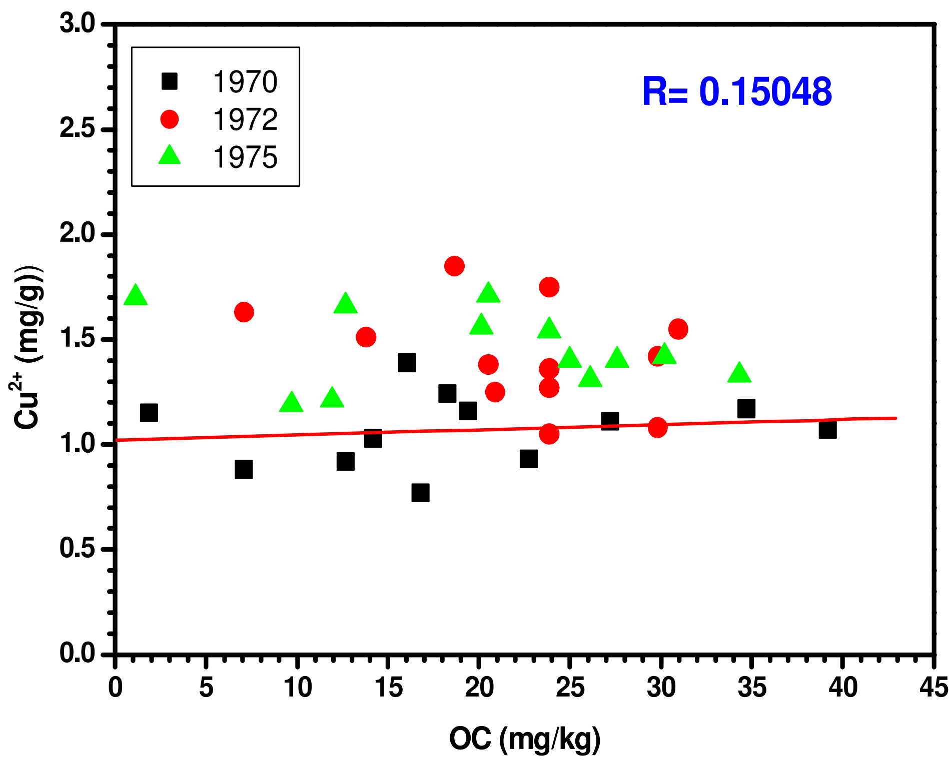

Figure 3k: Scatter Plot of Cu^{2+} against OC in Ilaro Soil

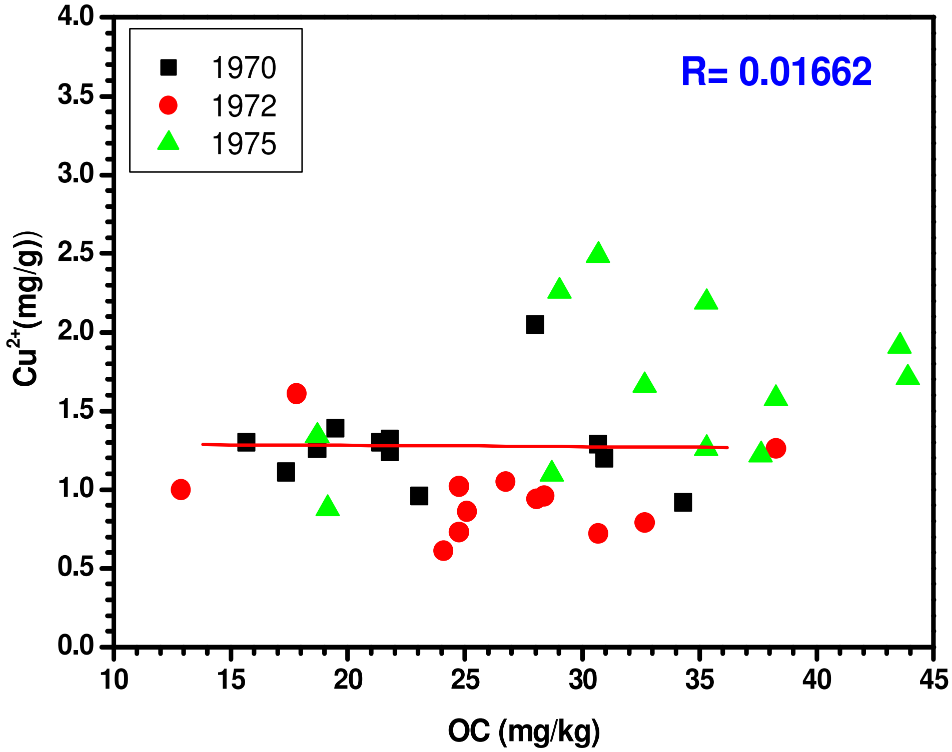

Figure 3l: Scatter Plot of Cu^{2+} against OC in Olokemeji Soil

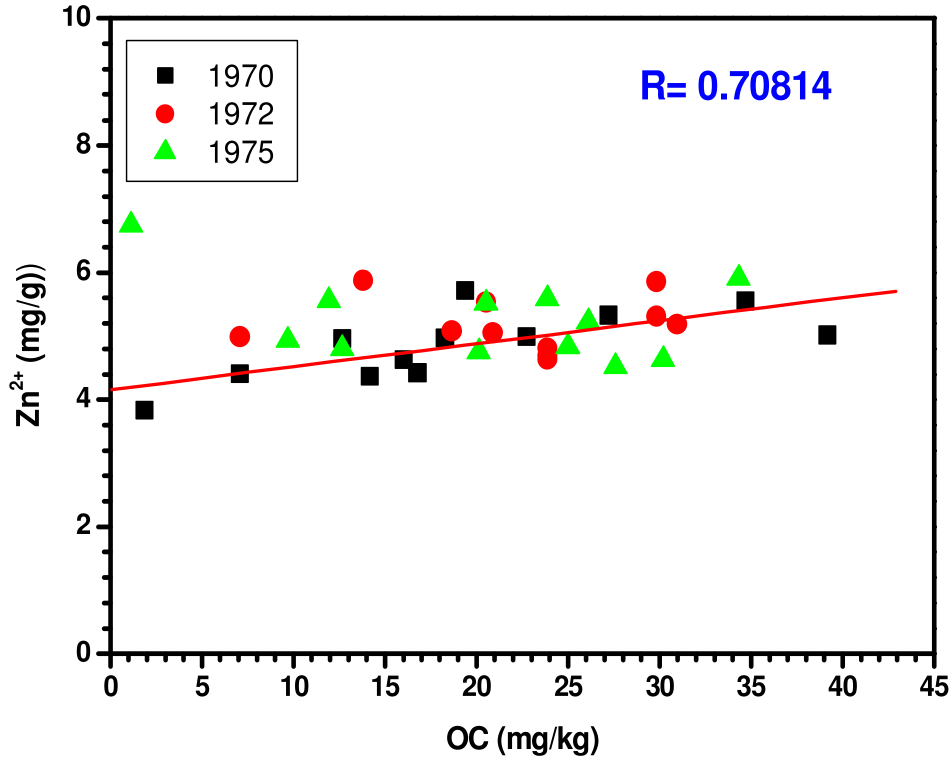

Figure 3m: Scatter Plot of Zn^{2+} against OC in Ilaro Soil

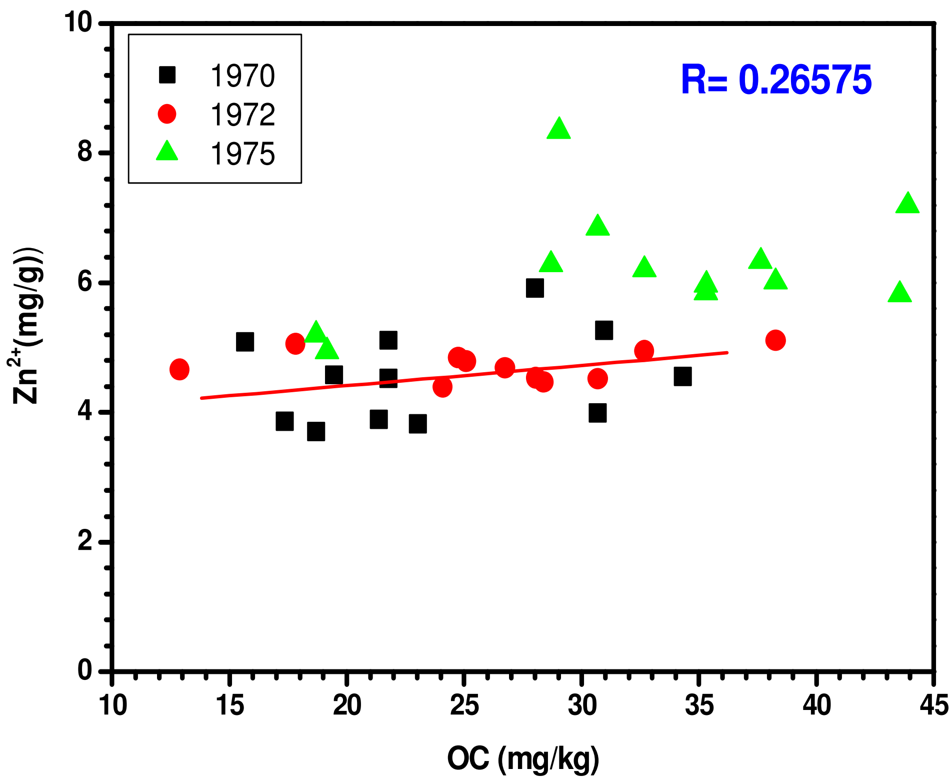

Figure 3n: Scatter Plot of Zn^{2+} against OC in Olokemeji Soil

Table 2a: Statistical Summary of Micro and Macro-minerals from The Two Sites

Parameter	Mean	Std. Deviation	Analysis N
N	2.4668	.95344	72
OC	24.0369	9.07294	72
P	27.8392	5.27478	72
K	.1439	.05767	72
Mn	62.3275	33.87016	72
Fe	41.5493	9.45008	72
Cu	1.3033	.36808	72
Zn	5.8289	5.96812	72

Table 2b: Descriptive Statistics for Ilaro Soil Chemical Analysis

Parameters	Mean	Std. Deviation	Analysis N
N	2.0806	.94097	36
OC	20.5678	9.02565	36
P	30.0489	3.20883	36
K	.1186	.04093	36
Mn	41.9781	18.18160	36
Fe	42.7672	6.02086	36
Cu	1.3153	.26514	36
Zn	6.4878	8.38623	36

Table 2c: Descriptive Statistics for Olokemeji Soil Chemical Analysis

Parameters	Mean	Std. Deviation	Analysis N
N	2.8531	.80731	36
OC	27.5061	7.79538	36
P	25.6294	6.00834	36
K	.1692	.06129	36
Mn	82.6769	33.83370	36
Fe	40.3314	11.91039	36
Cu	1.2914	.45194	36
Zn	5.1700	1.01611	36

Table 3a: Statistical Summary of Soil Chemical Nutrient of Olokemeji Plantation Soil Planted 1970

1970	A- HORIZON					B- HORIZON				
PARAMETER	AVER	MIN	MAX	STDEV	CV%	AVER	MIN	MAX	STDEV	CV%
N (mg/kg)	2.65	1.94	3.21	0.53	20	2.25	1.63	3.56	0.69	30.67
OC (mg/kg)	25.53	18.70	30.96	5.08	19.9	21.66	15.67	34.32	6.63	30.61
P (mg/kg)	21.94	7.26	29.16	8.96	40.84	21.12	8.47	29.75	8.31	39.35
K (Cmol/kg)	0.13	0.04	0.23	0.07	53.85	0.13	0.09	0.17	0.03	23.08
Mn (mg/g)	54.04	21.75	107.06	28.27	52.31	46.31	29.62	66.53	12.27	26.5
Fe (mg/g)	51.07	32.45	73.44	16.82	32.94	51.10	37.24	76.67	14.38	28.14
Cu (mg/g)	1.33	0.96	2.05	0.37	27.82	1.22	0.92	1.39	0.18	14.75
Zn (mg/g)	4.64	3.70	5.92	0.92	19.83	4.42	3.86	5.09	0.47	10.63

Table 3b: Statistical Summary of Soil Chemical Nutrient of Olokemeji Plantation Soil Planted 1972

1972	A- HORIZON					B- HORIZON				
PARAMETER	AVER	MIN	MAX	STDEV	CV%	AVER	MIN	MAX	STDEV	CV%
N (mg/kg)	3.04	2.57	3.97	0.54	17.76	2.39	1.34	3.18	0.68	28.45
OC (mg/kg)	29.32	24.75	38.28	5.25	17.91	23.05	12.87	30.69	6.61	28.68
P (mg/kg)	27.08	23.55	32.64	3.61	13.33	26.61	24.65	28.39	1.54	5.79
K (Cmol/kg)	0.16	0.13	0.19	0.02	12.5	0.15	0.10	0.18	0.03	20
Mn (mg/g)	82.10	67.11	116.03	17.67	21.52	70.87	61.54	77.45	6.03	8.51
Fe (mg/g)	34.87	29.91	41.82	4.60	13.19	32.98	29.12	40.54	4.27	12.95
Cu (mg/g)	0.94	0.73	1.26	0.19	20.21	0.98	0.61	1.61	0.35	35.71
Zn (mg/g)	4.81	4.47	5.11	0.22	4.57	4.67	4.39	5.06	0.25	5.35

Table 3c: Statistical Summary of Soil Chemical Nutrient of Olokemeji Plantation Soil Planted 1975

1975	A- HORIZON					B- HORIZON				
PARAMETER	AVER	MIN	MAX	STDEV	CV%	AVER	MIN	MAX	STDEV	C.V%
N (mg/kg)	3.33	1.94	4.55	0.88	26.43	3.33	1.94	4.55	0.88	26.43
OC (mg/kg)	32.10	18.70	43.89	8.49	26.45	32.10	18.70	43.89	8.49	26.45
P (mg/kg)	28.55	21.75	32.13	3.52	12.33	28.55	21.75	32.13	3.52	12.33
K (Cmol/kg)	0.26	0.20	0.29	0.03	11.54	0.26	0.20	0.29	0.03	11.54
Mn (mg/g)	128.36	111.04	150.27	12.62	9.83	128.36	111.04	150.27	12.62	9.83
Fe (mg/g)	35.73	32.34	38.63	2.30	6.44	35.73	32.34	38.63	2.30	6.44
Cu (mg/g)	1.78	1.22	2.49	0.50	28.09	1.78	1.22	2.49	0.50	28.09
Zn (mg/g)	6.68	5.20	8.34	1.06	15.87	6.68	5.20	8.34	1.06	15.87

Table 3d: Statistical Summary of Soil Chemical Nutrient of Ilaro Plantation Soil Planted 1970

1970	A -HORIZON					B -HORIZON				
PARAMETER	AVER	MIN	MAX	STDEV	CV%	AVER	MIN	MAX	STDEV	C.V%
N (mg/kg)	2.47	1.66	4.06	0.88	35.63	1.51	0.19	3.60	1.17	77.48
OC (mg/kg)	23.81	16.04	39.17	8.48	35.62	14.55	1.87	34.69	11.23	77.18
P (mg/kg)	29.75	23.80	35.19	5.07	17.04	28.86	24.82	33.15	3.38	11.71
K (Cmol/kg)	0.13	0.10	0.21	0.04	30.77	0.11	0.06	0.25	0.07	63.64
Mn (mg/g)	37.72	26.22	46.83	7.08	18.77	25.89	14.91	35.54	7.89	30.48
Fe (mg/g)	43.15	39.53	47.41	3.27	7.58	41.44	35.90	46.53	3.76	9.07
Cu (mg/g)	1.15	0.93	1.39	0.16	13.91	0.99	0.77	1.17	0.16	16.16
Zn (mg/g)	5.11	4.63	5.72	0.37	7.24	4.59	3.83	5.55	0.59	12.85

Table 3e: Statistical Summary of Soil Chemical Nutrient of Ilaro Plantation Soil Planted 1972

1972	A -HORIZON					B -HORIZON				
PARAMETER	AVER	MIN	MAX	STDEV	CV%	AVER	MIN	MAX	STDEV	CV%
N (mg/kg)	2.03	0.12	3.21	1.15	56.65	2.03	0.74	2.48	0.68	33.5
OC (mg/kg)	24.31	13.80	30.96	6.96	28.63	20.20	7.09	23.87	6.76	33.47
P (mg/kg)	29.10	24.06	31.47	2.74	9.42	30.77	28.90	32.47	1.41	4.58
K (Cmol/kg)	0.14	0.11	0.20	0.03	21.43	0.12	0.08	0.15	0.03	25
Mn (mg/g)	55.24	36.27	92.62	19.95	36.12	37.34	21.26	82.93	23.16	62.02
Fe (mg/g)	43.46	35.32	56.03	6.99	16.08	44.23	30.71	54.04	9.00	20.35
Cu (mg/g)	1.37	1.08	1.55	0.17	12.41	1.49	1.05	1.85	0.31	20.81
Zn (mg/g)	5.47	5.05	5.88	0.35	6.4	13.25	4.64	55.30	20.60	155.47

Table 3f: Statistical Summary of Soil Chemical Nutrient of Ilaro Plantation Soil Planted 1975

1975	A- HORIZON					B- HORIZON				
PARAMETER	AVER	MIN	MAX	STDEV	CV%	AVER	MIN	MAX	STDEV	CV%
N (mg/kg)	2.46	1.24	3.56	0.76	30.89	1.99	1.01	3.13	0.98	0.49
OC (mg/kg)	19.65	1.12	34.32	11.65	59.29	20.89	9.70	30.21	8.27	39.59
P (mg/kg)	32.43	28.48	36.21	2.99	9.22	29.38	27.37	33.58	2.38	8.1
K (Cmol/kg)	0.13	0.10	0.18	0.03	23.08	0.10	0.07	0.12	0.02	20
Mn (mg/g)	58.33	33.68	79.24	16.04	27.5	37.36	28.08	53.54	9.71	25.99
Fe (mg/g)	44.69	36.58	52.31	5.22	11.68	39.64	33.21	52.49	7.09	17.89
Cu (mg/g)	1.47	1.21	1.71	0.21	14.29	1.44	1.19	1.66	0.16	11.11
Zn (mg/g)	5.76	5.23	6.75	0.53	9.2	4.74	4.52	4.93	0.15	3.16

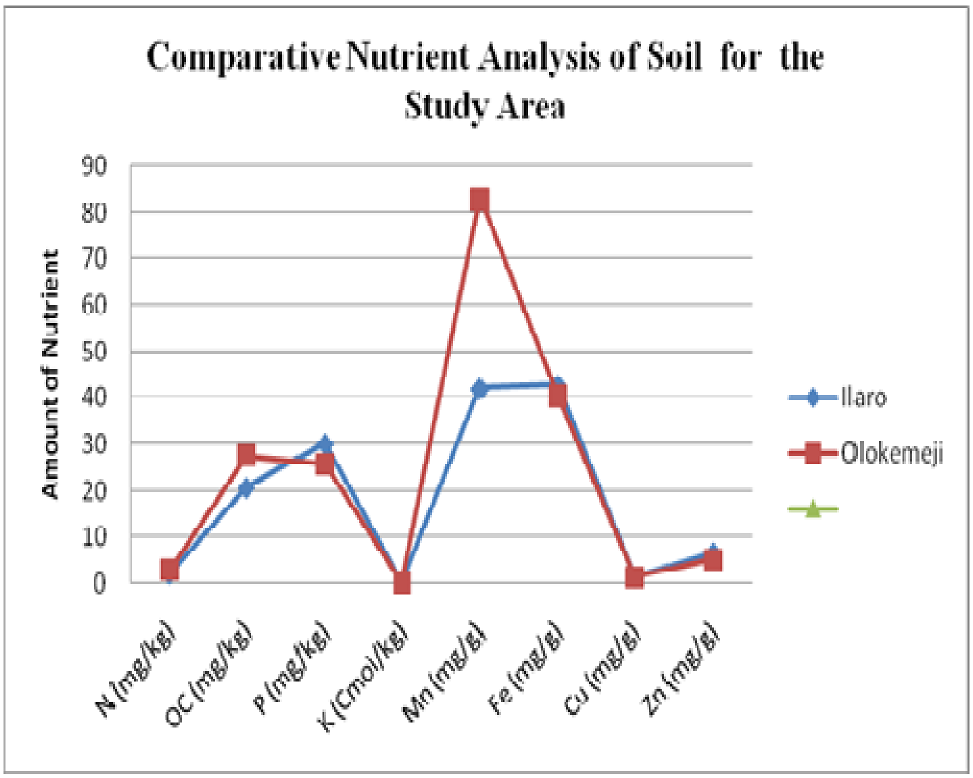

Figure 3o: Comparative Soil Nutrient distribution for the Study Sites

The tables' 3a-3f and figures 3o show the variations in the soil chemical nutrients according to different depths of soil under different tree ages. The laboratory analysis result of Nitrogen (N) for the top soil and sub-soil (A and B horizon) respectively revealed a range values of (3.21±0.27, 3.57±2.93), (4.06±2.30 ,3.60±2.50) with average value of ((2.65,2.47),(2.25,1.51)) and standard deviation values of ((0.53,0.88),(0.69,1.17)) for Olokemeji and Ilaro plantation aged 41 established in 1970 respectively. For plantation established in 1972 which by now is 43 years of age, the total Nitrgen (N) range values are (3.97±1.40, 3.18±1.44), (3.21±3.09, 2.48±1.74) with average value of ((3.04,2.39),(2.03,2.03)) and standard deviation value of

((0.054, 0.68),(1.15,0.68)) for Olokemeji and Ilaro plantation respectively while a range value of (4.55±2.61, 4.55±2.61), (3.56±2.32 ,3.13±2.12) with average values of ((3.33,3.33),(2.46,1.99)) and standard deviation values of ((0.88,0.88),(0.76,0.98)) for Olokemeji and Ilaro plantation established in 1975 respectively(see 3a-3f and figures 3o).

Total Nitrogen (N) levels were far from the highest values reported for mineral soils (Smith, 1994). Our results were in agreement with those reported in previous studies for soil total N status (Montangnini & Sancho, 1994; Fisher, 1995). Parton (1994) suggested that higher N levels occurred in undisturbed forests, due to a higher number of N-fixing trees. One possible explanation was a higher plant litter production in the natural forest and in mixed-tree plantations.

The result of Potassium (K) (see tables and figs. 5.3a to 5.3h and figs. 5.3a to 5.3m respectively) for the top soil and sub-soil (A and B horizon) revealed a range value of (0.23±21.90, 0.17±0.08), (0.21±0.11, 0.25±0.19) with average value of ((0.13, 0.13), (0.13, 0.11)) and standard deviation values of ((0.07,0.03), (0.04,0.07)) for Olokemeji and Ilaro plantation established in 1970 respectively. For 1972, the Potassium (K) range values are (0.19±0.06, 0.18±0.08), (30.20±0.09, 0.15±0.07) with average value of ((0.16,0.15),(0.14,0.12)) and standard deviation value of ((0.02, 0.03),(0.03,0.03)) for Olokemeji and Ilaro plantation established in 1972 respectively while a range value of (0.29±0.09, 0.29±0.09), (0.18±0.08 ,0.12±0.05) with average values of ((0.26,0.26), (0.13,0.10)) and standard deviation value of ((0.03,0.03), (0.03,0.02)) for Olokemeji and Ilaro plantation established in 1975 respectively.

The result of Manganese (Mn) for the top soil and sub-soil (A and B horizon) revealed a range value of (107.06±85.31, 66.53±36.91), (46.83±20.61,35.54±20.63) with average values of ((54.04,46.31),(37.72,25.89)) and standard deviation values of ((28.27,12.27),(7.08,7.89)) for Olokemeji and Ilaro plantation established in 1970 respectively. For 1972, the Manganese (Mn) range values are (116.03±49.92, 77.45±15.91), (92.62±56.35, 82.93±61.67) with average value of ((82.10,70.87),(55.24,55.24)) and standard deviation value of ((17.67, 6.03),(19.95,19.95)) for Olokemeji and Ilaro plantation established in 1972 respectively while a range value of (150.27±39.23, 150.27±39.23), (79.24±45.56 ,53.54±25.46) with average values of ((128.36,128.36),(58.33,37.36)) and standard deviation value of ((12.62,12.62),(16.04,9.71)) for Olokemeji and Ilaro plantation established in 1975 respectively(see 3a-3f and figures 3o respectively).

The result of Iron (Fe) for the top soil and sub-soil (A and B horizon) revealed a range value of (73.44±40.99, 76.67±39.43), (47.41±76.67,46.53±10.63) with average values of ((51.04,51.10),(43.15,41.44)) and standard deviation values of ((16.82,14.38),(3.27,3.76)) for Olokemeji and Ilaro plantation established in 1970 respectively. For 1972, the Iron (Fe) range values are (41.82±11.91,40.54±11.42), (56.03±49.04, 54.04±23.33) with average value of ((34.87. 32.98),(43.46,44.23)) and standard deviation value of ((4.60, 4.27),(6.99,9.00)) for Olokemeji and Ilaro plantation established in 1972 respectively while a range value of (38.63±6.29, 38.63±6.29), (52.31±15.73 ,52.49±19.28) with average values of ((35.73,35.73),(44.69,39.64)) and standard deviation value of ((2.30,2.30),(5.22,7.09)) for Olokemeji and Ilaro plantation established in 1975 respectively(see tables and figs. 5.3a to 5.3h and figs. 5.3a to 5.3m respectively)The result of Cupper (Cu) for the top soil and sub-soil (A and B horizon) revealed a range value of (2.05±1.09, 1.39±0.46), (1.39±0.46,1.17±0.49) with average values of ((1.33,1.22),(1.15,0.99)) and standard deviation values of ((0.37,0.18),(0.16,0.16)) for Olokemeji and Ilaro plantation established in 1970 respectively. For

1972, the Cupper (Cu) range values are (1.26±0.53, 1.61±1.0), (1.55±0.47, 1.85±0.07) with average value of ((0.94.0.98),(1.37,1.49)) and standard deviation value of ((0.19, 0.35),(0.17,0.31)) for Olokemeji and Ilaro plantation established in 1972 respectively while a range value of (2.49±1.27, 2.49±1.27), (1.71±0.50 ,1.66±0.47) with average values of ((1.78.1.78),(1.47,1.44)) and standard deviation value of ((0.50,0.50),(0.21,0.16)) for Olokemeji and Ilaro plantation established in 1975 respectively. The result of Zinc (Zn) for the top soil and sub-soil (A and B horizon) revealed a range value of (5.92±2.222, 5.09±1.23), (5.72±1.09,5.55±1.72) with average values of ((4.64,4.42),(5.11,4.59)) and standard deviation values of ((0.92,0.47),(0.37,0.59)) for Olokemeji and Ilaro plantation established in 1970 respectively. For 1972, the range values are (5.11±0.46, 5.06±0.67), (5.88±0.83, 55.30±48.66) with average value of ((4.81.4.67),(5.47,13.25)) and standard deviation value of ((0.22, 0.25),(0.35,20.60) for Olokemeji and Ilaro plantation established in 1972 respectively while a range value of (8.34±2.14, 8.34±2.14), (6.75±1.52 ,4.93±0.41) with average values of ((6.68.6.68),(5.76,4.74)) and standard deviation value of ((1.06,1.06),(0.53,0.15)) for Olokemeji and Ilaro plantation established in 1975 respectively(see 3a-3f and figures 3o respectively).

The result of Organic carbon (OC) for the top soil and sub-soil (A and B horizon) revealed a range values of (30.96±12.26, 3.56±1.93), (39.17±23.81, 34.69±32.82) with average values of ((25.53, 2.25), (23.81, 14.55)) and standard deviation values of ((0.53, 0.69), (8.48, 11.23)) for Olokemeji and Ilaro plantation established in 1970 respectively. For 1972, the Organic carbon (OC) range values are (38.28±3.53, 30.69±17.82), (30.96±17.16, 23.87±16.78) with average values of ((29.32,23.05), (24.31,20.20)) and standard deviation value of ((5.25, 6.61), (6.96,6.76)) for Olokemeji and Ilaro plantation established in 1972 respectively while a range values of (43.89±25.19, 43.89±25.19), (34.32±33.20 ,30.21±20.51) with average values of ((32.10,32.10), (19.65,20.89)) and standard deviation value of ((8.49,8.49),(11.65,8.27)) for Olokemeji and Ilaro plantation established in 1975 respectively(see 3a-3f and figures 3o respectively)y.

The amount of OC in soils represents a balance between primary productivity, as influenced by environmental conditions (Parton *et al*., 1987; Yonker *et al*., 1988; Bulluck *et al*., 2002) and biologically-mediated decomposition processes (Sanginga *et al*., 1992; Schroth *et al*., 2002). Van Noordwijk *et al*. (1997) in Indonesia, Schroth *et al*. (2002) in Amazonia reported decreasing carbon content in the topsoil from natural forest to secondary forest, tree plantation and perennial crops (*Theobroma cacao*).

The result of available phosphorous (P) for the top soil and sub-soil (A and B horizon) revealed a range values of (29.16±21.90, 29.75±21.27), (35.19±11.39, 33.15±8.33) with average values of ((21.94,21.12), (29.75,28.86)) and standard deviation values of ((8.96,8.31), (5.07,3.38)) for Olokemeji and Ilaro plantation established in 1970 respectively. For 1972, the Phosphorous (P) range values are (32.64±9.09, 28.39±3.74), (31.47±7.41, 32.47±3.57) with average values of ((27.08,26.61), (29.10,30.77)) and standard deviation value of ((3.61, 1.54), (2.74,1.41)) for Olokemeji and Ilaro plantation established in 1972 respectively while a range value of (32.13±10.38, 32.13±10.38), (36.21±3.73 ,33.58±6.21) with average values of ((28.55,28.55), (32.43,29.38)) and standard deviation value of ((3.52,3.52), (2.99,2.38)) for Olokemeji and Ilaro plantation established in 1975 respectively(3a-3f and figures 3o respectively)y.

Most soils are of mineral origin, but their topsoil contains organic matter that, in spite of its low content, is of great importance to many aspects of soil fertility and plant growth. Soil organic matter (SOM) can range from less than 1 percent in many tropical arid and semi-arid soils of the plains to 5 percent or more in temperate regions or under forest vegetation. The average composition of SOM is 47 percent C, 44 percent O, 7 percent H, 2 percent N and very small amounts of other elements. More than half of SOM consists of carbohydrates, 10–40 percent is the resistant material lignin and the rest consists of compounds of N. The whole complex of organic matter along with soil organisms and soil flora is of vital importance to soil fertility. SOM contains the well-decomposed fine humus fraction, small plant roots, and members of the plant (flora) and animal (fauna) kingdoms. SOM plays a role far greater than its share of the soil volume. It is a virtual storehouse of nutrients, plays a direct role in cat ion exchange and water retention, releases nutrients into the soil solution and produces acids that affect the fixation and release of other nutrients. SOM or “humus” reaches equilibrium during soil formation. Wet and/or cold soil conditions tend to increase the humus content, whereas high temperatures of tropical climates and cropping procedures promote its decomposition. The C: N ratio provides a general index of the quality of SOM, being in the range of 10–15:1 for fertile soils. When organic manures or green manures are added, these become a part of the organic pool of the soil.

Comparing spatio-temporal pattern of the chemical nutrients of the soil of the top soil and sub-soil for plantation established in 1970 for both sites at the top soil depth (Horizon A), it is evident that Nitrogen context of Olokemeji is higher than that of Ilaro; likewise the organic carbon content wish is also higher at Olokemeji. There is however a deviation on the phosphorus content as Ilaro had more phosphorus at this depth in the 1970 plantation than Olokemeji. There is no different in the Potassium (K) composition of both areas. Other micro nutrients that were tested which include Manganese (Mn) , Iron (Fe) and copper (Cu) were also more abundant at Olokemeji except for zinc (Zn) that was higher at Ilaro. On the other hand, the B-Horizon of 1970 plantation of both sites also showed higher composition of Nitrogen (N), organic carbon (Oc), Potassium, manganese (Mn), Iron (Fe), Copper (Cu) at Olokemeji than at Ilaro, except for Phosphorous (CP) and zinc (Zn) which remained higher at Ilaro than at Olokemeji. It is however worthy of note that the concentrations of these nutrients are higher at the A-Horizon of this tree age than at the B-Horizon (see 3a-3f and figures 3o).

For plantation established in 1972, the A-Horizon shows higher concentrations of N, OC, K, Mn, Fe and Cn at Olokemeji than at Ilaro with the exception of P and Zn which remained higher at Ilaro than Olokemeji. The same results at A-Horizon were replicated at the B-Horizon. However, concentrations of nutrients were higher at A-Horizon than B-Horizon as evidence in 1970 as well (see 3a-3f and figures 3o).

In the case of plantation established in 1975, the A-Horizon also show higher concentrations of N, OC, K, Mn, Fe and Cu at Olokemeji, however, in this age serie, Cu was higher at Olokemeji than at Ilaro which is a deviations from the other two plantation ages. Only phosphorous (P) remained higher at Ilaro than at Olokemeji. The higher P concentration in Ilaro could be attributed to the lower Fe concentration present in the soil. The higher P concentration at Ilaro could be attributed to the lower Fe concentrations while the lower P concentrations at Olokemeji could be attributed to the higher Fe concentration. This is evident in the correlation of P against Fe. P and Fe show a negative correlation which implies that they are inversely related (see 3a-3f and figures 3o).

The following hypotheses were tested: There is no statistical significant difference between the soil chemical (Nutrients) properties of the basement (Olokemeji) and the sedimentary (Ilaro) rock formation (Primary hypothesis). The secondary hypotheses are: 1. There is no statistical significant difference between the two locations on means concentration of nutrient parameters studied acrros the three year periods under investigation. 2. There is no statistical significant difference among the three years studied on means concentration of nutrient parameters studied. 3. There is no statistical significant difference between the two horizons on means concentration of nutrient parameters studied.

The test shows that there is a statistical significant difference among the nutrients parameters (Nitrogen (N) Organic carbon (OC), Potassium (K), Phosphorous (P), Manganese (Mn) iron (Fe), cupper (Cu) and Zinc (Zn)).

For Location, there is a statistical significant difference between the two locations on means concentration of chemical parameters studied.

For the horizon, there is a statistical significant difference between the two horizons A and B on the mean concentration of nutrient parameters.

For the three years, there is a statistical significant difference between 1970 and 1972, 1970 and 1975 as well as 1972 and 1975 on the mean concentration of the parameters studied. In conclusion therefore, among the years under investigation, 1975 has the highest mean concentration followed by 1972 and 1970. This shows that there is temporal effect on the concentrations of these nutrients.

In conclussion, the mean concentration of the nutrient parameters is higher in the A horizon with mean value of 21.270 compared to B-horizon with 19.505 which is an attestation to the fact that there is higher concentrations of basic nutrients at the A horizon because of the effect of the organic matter through the interaction of the microbial organic activities of leave litters and microorganisms which produces humus that enhances Plant growth while at the B horizon which is the Parent materials zone with little or no humus concentration

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